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Mechanism of Catalytic Ignition and Combustion of Solid Rocket Propellants (U)

by

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This bimonthly letter report describes the work in progress under Contract No. DA-28-017-AMC-2222(A). The investigators are Dr. Leonard Dauerman and Messrs. George E. Salser and Yuji A. Tajima. Assistance in data reduction is being rendered by Messrs. Everett R. Allen and Vincent Mancini.

1. Introduction

The objective is to investigate the mechanism of action of burning rate catalysts in the ignition and combustion of double-base propellants. Experimentally, the surface temperatures of burning propellant strands are measured and chemical-kinetic investigations of the products of degradation of the regressing surface are carried out. Heat is supplied by an arc image furnace for the ignition studies.

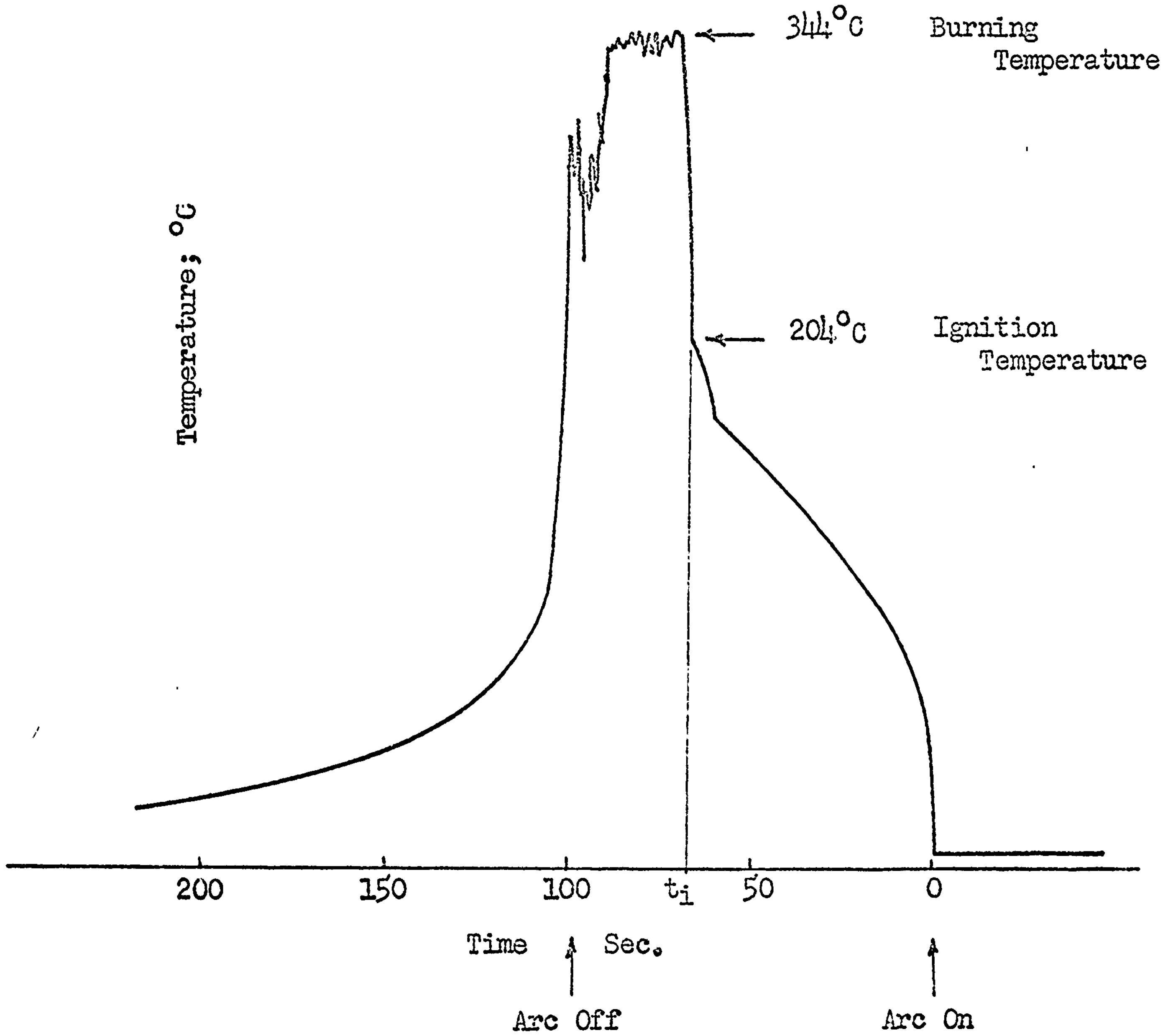
2. Progress Report

2.1. Ignition Times and Temperatures

A typical surface temperature vs time plot of an igniting propellant strand is shown in Fig. 1; the example is that of Lot 2885, uncatalyzed propellent. The profile is self-explanatory. The temperature at which a sudden increase in temperature occurs has been designated the ignition temperature; the corresponding time is then the igntion time. The steady-state temperature has been designated as the "burning temperature". These values as a function of relative heat flux are tabulated in Table I. for those runs in which temperature-time records have been obtained.

Fig. 1

Temperature-Time Profile
Double-Base Propellant
"Burned" at 10 Torr



t_i = Ignition Time

Table I.

Ignition Characteristics

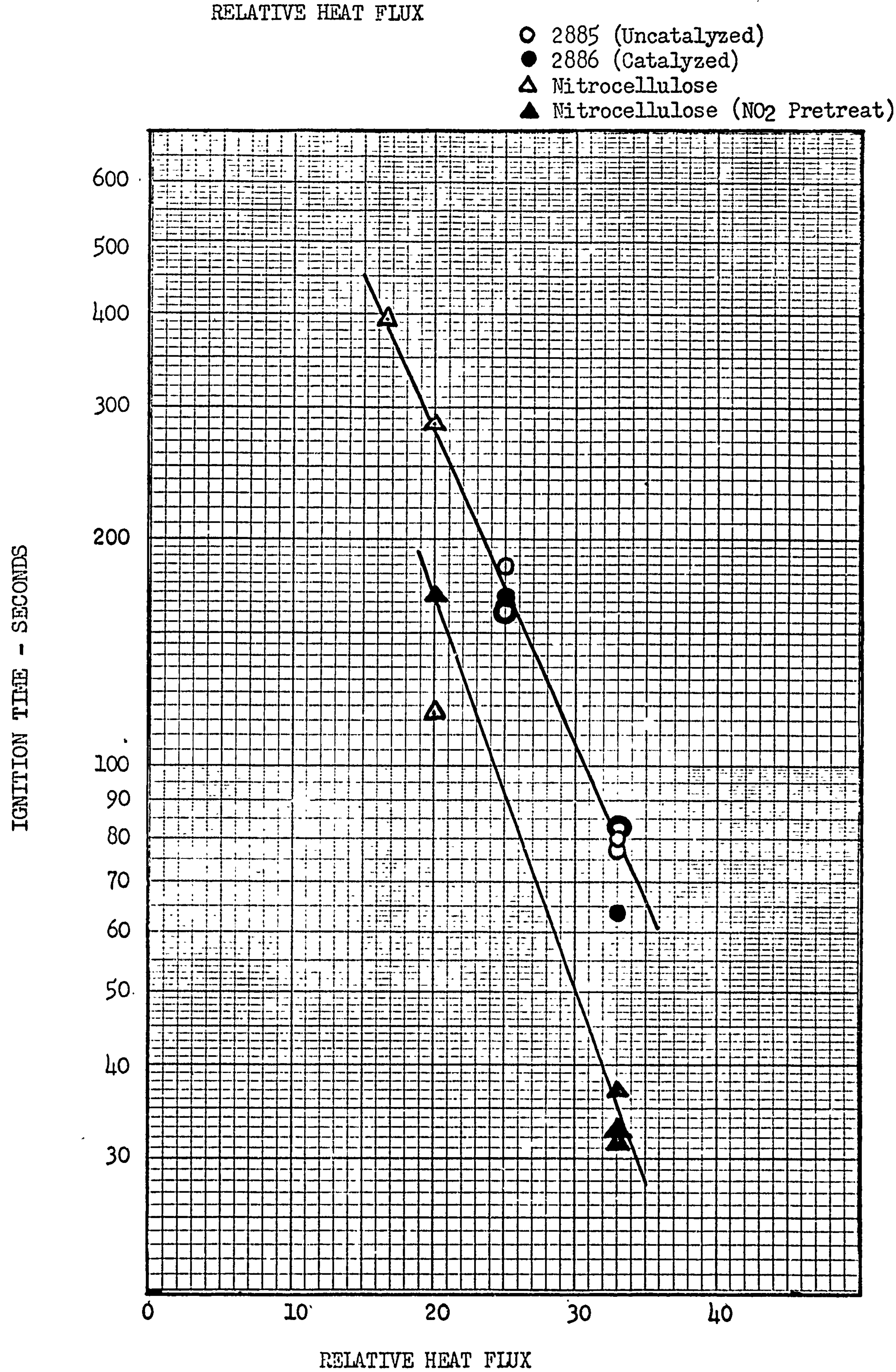
Relative Heat Flux	Ignition Time Seconds	Ignition Time °C.	Burning Temp. °C.
	Lot 2885 (uncatalyzed		
100	67	211	335
33	80	220	348
	82	215	339
	78	227	344
25	184	210	335
	158	190	335
	Lot 2886 (catalyzed)		
33	63	225	390
	82	209	370
25	157	207	355
	165	195	335
	154	210	355
	Nitrocellulose		
20	286	205	435
	118	205	445
16.3	393	192	-
	Nitrocellulose (NO_2 pretreat)		
33	33	200	415
	37	205	410
	32	210	428
20	169	210	-

A plot of log t_i (ignition time) vs relative heat flux is given in Fig. 2. Ignition times for the basic matrix, catalyzed propellant (lead stearate), and nitrocellulose fall pretty well on a straight line. On the other hand, NO_2 pretreatment of nitrocellulose appears to markedly decrease the igntion time. Pretreatment consists of exposing the NC pellet to 9.35 torr NO_2 for 5 minutes. The NO_2 is then flushed out, prior to heating, with the carrier gas which is a mixture of 1% Ar in He. Two points did not fall on the linear plot; viz., one NC test at 20% relative heat flux and a sample of 2885 at 100% relative heat flux. t_i for the latter test is 67 seconds which appears to be inordinately long; t_i of NC under the same heating rate measured approximately 3-1/2 seconds (visual observation, no T vs t record).

The ignition temperature appears to be independent of the heating rate and the same for uncatalyzed double-base, catalyzed double-base and nitrocellulose. On the other hand the burning temperature is much higher for nitrocellulose than double-base and higher for nitrocellulose without NO_2 pretreat; i.e., NO_2 pretreat appears to lower the burning temperature of nitrocellulose. In the case of double-base propellants, the burning temperature may be higher for higher heating rates. It is interesting to note that our values of burning temperatures for double-base agree quite well with the surface reaction zone temperatures of burning double-base measured by Sabadell, Wenograd and Summerfield[1]; viz., 268, 333, and 332°C. at 150, 100 and 50 psig, respectively.

Fig. 2

IGNITION TEMPERATURE
VS
RELATIVE HEAT FLUX



2.2. Mass Spectral Data

The films (mass spectra) from the various runs (see last bi-monthly report, No. 1) have been read. It is difficult to make direct comparisons between run records because the spectra could not be re-corded at different instrument attenuations simultaneously. With the present read-out system, it is only possible to record at one attenuation per run. Thus, it may happen that intense peaks go off scale, that less intense peaks record weakly, or both. This limitation also decreases the precision and accuracy of our mass spectral analysis. Ideally, the mass spectra should be recorded during a firing run at 3 to 5 attenuations simultaneously. We hope to do this soon by use of a gang of amplifiers and multi-channel magnetic tape recording. Time and surface reaction zone temperature can also be recorded simultaneously on other channels. A particularly neat procedure to analyze the mag-tape would be to feed it as imput data to a hybrid computor and obtain the reduced data in digital form. However, this computor is not presently available at New York University so the present plan is to read it out on a Visicorder.

The data from runs D-4, D-6, and D-8 are presently being analyzed; they are uncatalyzed double-base, catalyzed double-base, and nitrocellulose, respectively. D-14, nitrocellulose with NO_2 pretreat, also is to be analyzed for comparison with D-8. These runs have been chosen for analysis since the mass spectra vs time records are the best ones for each particular sample.

3. Program

The mass spectrometric (chemical) analysis of runs D-4 and D-6 should be completed and considerable progress made on D-8 and D-14 during the next reporting period.

We hope to carry out trial runs to test the applicability of the mag-tape-visicorder read-out system.

The work is approximately 45% completed and the expenditures thus far is 45% of the funds allocated to this project.

4. Reference

1. A.J. Sabadoll, J. Wencgrad, and M. Summerfield, "The Measurement of Temperature Profiles Through Solid Propellant Flames Using Fine Thermocouples", AIAA Solid Propellant Rocket Conference, Palo Alto, California, January 29-31, 1964. Preprint No. 64-106.